



# Participatory agroecological research on climate change adaptation improves smallholder farmer household food security and dietary diversity in Malawi



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## ABSTRACT

This study examines whether agroecological farming practices, when employed by highly vulnerable households in sub-Saharan Africa, can improve food security and dietary diversity. The research involved a four-year study with 425 smallholder households, selected purposively based on high levels of food insecurity and/or positive HIV status. The households carried out agroecological experiments of their own choosing over a four-year period. Baseline ( $n = 306$ ) and follow-up ( $n = 352$ ) surveys were conducted in 2011 and 2013 respectively to assess changes in farming practices, food security, crop diversity and dietary diversity. Longitudinal mixed effects models were used with 203 matched households to estimate determinants of change in food security and dietary diversity at the population level. Qualitative interviews and focus groups were also conducted to provide depth to the survey findings. The findings show that participatory agroecology experimentation increased intercropping, legume diversification and the addition of compost, manure and crop residue amendments to the soil. Intercropping was associated with food security and the use of organic soil amendments was associated with gains in dietary diversity in bivariate analysis. Household food security and dietary diversity increased significantly over a 2-year period. Importantly, multivariate models showed that spousal discussion about farming was strongly associated with increased household food security and dietary diversity. Households who discussed farming with their spouse were 2.4 times more likely to be food secure and have diverse diets. Addition of compost or manure to the soil significantly influenced dietary diversity. These findings indicate that poor, vulnerable farmers can use agroecological methods to effectively improve food and nutritional security in sub-Saharan Africa. The study also highlights how linking agroecology to participatory research approaches that promote farmer experimentation and gender equity also lead to greater health and well-being. The study sheds light on how agroecological approaches can rapidly improve food security and dietary diversity, even under conditions of acute social, health or ecological stress. It draws attention to issues of equity and farmer-led approaches in addressing food security and nutrition.

## 1. Introduction

Smallholder farmers in sub-Saharan Africa face multiple challenges

in sustaining a viable food system and are highly vulnerable to new climatic threats (Souza et al., 2015). Current climate change assessments indicate increased peak and seasonal mean temperatures, more

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erratic rainfall patterns, higher frequency and intensity of droughts and reduced crop yields in Africa (Intergovernmental Panel on Climate Change (IPCC, 2018; Nangombe et al., 2018). High levels of protracted food insecurity are prevalent in sub-Saharan Africa, with an estimated 1 in 3 people experiencing hunger (FAO et al., 2017). Child under-nutrition accounts for one-third of all child deaths annually, and there are persistent high rates of maternal and child undernutrition in Sub-Saharan Africa (FAO et al., 2017). Rural smallholders experience higher rates of malnutrition and food insecurity than urban households (FAO et al., 2018).

Hunger and malnutrition, however, do not occur in a political or social vacuum. Vulnerable groups are those with highest exposure, susceptibility and low adaptive capacity to cope with threats posed by food insecurity and climate change (Erickson et al., 2009). Vulnerability to climate change impacts may be increased by several socio-economic factors, including poverty, social status, and location in environmentally marginal areas (Ribot, 2014). Individuals and communities are more vulnerable to food insecurity and the potential effects of climate change based on availability of resources, access to and control over resources, geographical location and ability to adapt to change (Ribot, 2014). Within communities and households, different social roles (e.g. gender, class, ethnicity, health status) can determine who has greater access to food and who is at greater risk from climate change impacts (Eastin, 2018). Women's unequal role within households and communities – including higher workloads, lower decision-making and control over agricultural practices – has been shown to significantly impact household food security and nutrition (Carlson et al., 2015; Hyder et al., 2005). A recent multi-country economic analysis found gender equity to be a key determinant of child nutrition (Smith and Haddad, 2015), supporting the need for attention to these social dynamics. High rates of HIV prevalence in southern and eastern Africa also increase vulnerability to climate change and food insecurity (Aberman et al., 2014).

There are scientific and policy debates about how to produce food to address food security, healthy diets, climate change, social justice and environmental degradation (Conceição et al., 2016; Godfray and Garnett, 2014). Many current policies promote intensification methods through the use of fertilizer, hybrid seeds, pesticides, mechanized agriculture and irrigation with considerable evidence of adverse impacts on biodiversity, soil quality, groundwater, pollinators, and other ecosystem services (Diaz and Rosenberg, 2008; Gabriel et al., 2010; Goulson et al., 2015; Hector and Bagchi, 2007; IPES-Food, 2016). The United Nations Special Rapporteur on the Right to Food, the Food and Agricultural Organization and other international scientific bodies put forward agroecology as an alternative sustainable and equitable approach to producing food (De Schutter, 2010; HLPE, 2017; IPES-Food, 2016). Agroecology is a holistic approach to farming which applies ecological principles to the food system, through methods such as diversification, enhancing energy, water and nutrient flows, supporting soil health, and maximizing beneficial interactions between organisms to minimize toxic external inputs (Gliessman, 2015). Agroecology also emphasises local and indigenous knowledge, farmer experimentation, strengthening farmers' autonomy, local markets and social justice (Dumont et al., 2016). Participatory research methodologies are often used in agroecological research, since indigenous, local knowledge, experimentation and observation are important aspects of agroecology (Méndez et al., 2013).

Recent reviews have found that agricultural interventions alone are unlikely to have positive impacts on nutrition, but instead need to be combined with nutrition education or addressing social inequalities (Masset et al., 2012; Haddad, 2013). There are limited studies examining the links between agroecological approaches and food security and nutrition outcomes (Bezner Kerr et al., 2019). There is some evidence of food security and nutrition impacts from agroecological approaches, including biodiversity (Frison et al., 2011); legume intercrops (Bezner Kerr et al., 2010) and habitat protection for wild-sourced foods

(Powell et al., 2015). Some research shows evidence of agroecological methods increasing smallholder resilience to climate change and other environmental shocks (Holt-Giménez, 2002; Philpott et al., 2008; Rogé et al., 2014). In addition, agroecological efforts have shown evidence of improved food security and livelihoods (Kangmennaang et al., 2017; Lee et al., 2014; Méndez et al., 2010; Méndez et al., 2013; Oliver, 2016). Recent reviews of agroecological and diversified farming systems research have noted a gap in the impact of these approaches on whole food system, not just single crops, particularly in the Global South (Ponisio et al., 2015; Sanderson Bellamy and Ioris, 2017). There is a call for more rigorous studies on the food security and nutrition impacts of agroecological farming systems (Sanderson Bellamy and Ioris, 2017; Kremen et al., 2012; Kremen and Miles, 2012; Ponisio et al., 2015; Seufert et al., 2012). In particular, there are very few studies on agroecological methods in Sub-Saharan Africa, which test the potential for agroecological methods to address food security and nutrition (Sanderson Bellamy and Ioris, 2017). This study begins to address the gaps identified, with explicit attention to equity issues alongside food security and nutrition outcomes. The specific research objective of this study is *to test whether agroecological farming methods, which explicitly include participatory research and attention to social inequities, can improve food security and nutrition among highly vulnerable households*.

Malawi is located in southeastern Africa, with a current population of 16.4 million, over 80% of whom live in rural areas and rely on agriculture for their food and livelihoods (World Bank, 2017). Malawi is one of the poorest countries in the world, with an estimated per capita income of \$US320, and over 50% of the population living below the poverty line, with higher rates in rural areas (World Bank, 2017). An estimated one-quarter of Malawian households experience chronic food insecurity (FAO et al., 2017). Over 40 percent of children under 5 years of age are stunted, a measure of chronic food deprivation (FAO et al., 2017).

Previous research in Malawi identified women as being more vulnerable to food insecurity, in part due to unequal social status and roles, including high workloads, limited control over household resources and high rates of domestic and sexual violence (National Statistical Office (NSO) and ICF, 2017). While women play a key role in agricultural production, they are also responsible for child care, food processing, water and firewood collection and caring for the ill (Bezner Kerr et al., 2016b). These multiple roles combined with limited control over decision-making leave women in a particularly vulnerable context in relation to climate change and food security. Young women in particular often have limited control over resources and few livelihood options, leaving them in a vulnerable social context (Bryceson and Fonseca, 2006). There is an estimated 10 percent adult HIV infection rate in Malawi, with higher rates for women than men, and adolescent girls at greater risk of infection due to fewer educational, legal and social supports (Government of Malawi (GOM), 2014). HIV/AIDS contributes to and complicates household food insecurity (Dorward and Mwale, 2006; Hayes, 2016). AIDS-affected families are often short of labor, may have to sell their assets in order to pay for medical expenses, have greater nutritional needs, more care responsibilities; with HIV positive women more likely to experience higher food insecurity (Dorward and Mwale, 2006; Nyantakyi-Frimpong et al., 2016).

Malawi has prioritized investment in agricultural intensification, through the Farm Input Subsidy Program (FISP), first implemented in 2005, which provided about 1.5 million households with subsidized fertilizer and hybrid maize seeds (Chirwa and Dorward, 2013). This program, which accounts for 70 percent of the total budget of the Ministry of Agriculture, Irrigation and Water Development and 10 percent of the national budget, has contributed significantly to an increase in maize production and to a lesser extent income (Chirwa and Dorward, 2013). Nonetheless, food insecurity and child undernutrition remain high (FAO et al., 2018), leading to debates about policy appropriateness (Bezner Kerr, 2012; Ecker and Qaim, 2011; Lunduka et al., 2013; Messina et al., 2017). Dietary diversity, (the number of

different food groups consumed over a given time period), is a key determinant of nutritional status (Smith and Haddad, 2015) and is one of several measures of food security (Ruel, 2003). Malawi devotes over 70% of all arable land to maize production, and almost half of the Malawian diet consists of maize, contributing to high rates of micronutrient deficiencies and a leading cause of undernutrition (Ecker and Qaim, 2011; FAO et al., 2017).

## 2. Methodology

The research question of this study is: *can participatory research on agroecological farming methods and attention to social inequities improve highly vulnerable households' food security and nutrition?* A participatory research approach combined with pre-post longitudinal study design was used to examine changes in farming practices, food security and dietary diversity over a four-year period after 425 farmers selected different agroecological experiments to test. Using participatory action research principles, there was only a pre-post comparison, rather than including control households which would not receive any direct benefit from involvement in the research. The intervention included monthly discussions and community-based dialogue about social inequalities. Given the relational and socially embedded nature of food security, dietary diversity and smallholder farming practice (Webb et al., 2006), we also used qualitative methods to situate and give depth to our statistical findings from survey results (Miles et al., 2014).

### 2.1. Sampling methods and agroecological experiments

Thirty-one villages were randomly selected, 17 in northern Malawi, and 14 in central Malawi (Fig. 1). Purposive sampling was then used to select 425 participating households within these villages, with households invited to participate based on the following criteria: low food security, HIV status (if known) and/or youth. These criteria are indicators of vulnerability to both food insecurity and climate change. The participants received training on agroecological principles from a Malawian non-profit organization with experience in agroecology, gender, nutrition and participatory methods and then selected several methods to test. Households were asked to select any intervention(s) given their labour availability, food need, land ownership, soil characteristics, HIV status, and other social factors.

The range of agroecological methods included: 1) integration of trees (fruit trees and/or leguminous trees); 2) soil fertility and/or conservation methods, including the use of crop residues and compost; 3) crop diversification, including legumes, indigenous grains and tubers; and 4) livelihood diversification, such as small livestock (pigs or goats), making fuel-efficient stoves, and bee-keeping (Fig. 2). Livestock were initially managed at a community level: the participating farmers constructed a village corral for the animals, received 2 pigs per village and contributed feed (e.g. maize stalks). The first group of offspring were distributed to other participating farmers using the 'pass-on' model. Over 100 pigs and goats were distributed within the participating villages (1 per household) using this system. These practices are in line with agroecological principles, including diversified crop rotations, integration of crops and mixed livestock systems, agroforestry, and development of local markets from farm products (Gliessman, 2015). The research team regularly visited all participating farmers to provide inputs and guidance in the agroecological experiments, for example, if farmers were having difficulty with a particular insect pest, the team tried to find appropriate agroecological strategies to address the pest. Participating farmers not only designed and carried out their own experiments, they also held group discussions at the village level on a monthly basis to share experiences and did exchanges with other farmers. The Malawian NGO made monthly field visits to farmers. There were also facilitated discussions on social inequalities, including gender and health status, and ways to address these inequalities (Bezner Kerr et al., 2016a), with the support of the research team. Field notes

were taken during these discussions.

### 2.2. Quantitative data collection

A baseline survey was carried out with randomly selected participating households ( $n = 306$ ) in 2011 (t1) to assess general household characteristics, farming practices, number of fields planted, and land ownership (Fig. 3). The baseline survey also assessed wealth level, household food security, dietary diversity, sources of agricultural knowledge, and farmers' perceptions and ideas about climate change. Wealth was measured by asking households if they owned any specific assets (e.g. radio, cell phone, bicycle, car, tobacco press). The list was generated through 1) using standardized list from the Living Standards Measurement Survey in Malawi (National Statistical Office (NSO), 2014) and 2) modifying it based on the long-term experience of research team members working in rural areas and observing key differences in wealth based on assets. A modified asset index was generated by adding up the number of assets they owned, and then using principal component analysis to create a weighted asset score, which was categorized into quintiles to give us the wealth categories: Very poor; Poor; Middle; Better off and Rich. This is a modified approach used in assessing wealth in many studies (Rutstein and Johnston, 2004). Food security was measured using a standardized set of questions from the Household Food Insecurity Access Scale (Coates et al., 2007). Dietary diversity was assessed using standardized questions which asked whether any household member had eaten food items from a given set of food groups (Swindale and Bilinsky, 2006). Trained enumerators administered the baseline survey.

The baseline survey was followed by implementation of participatory farmer-led experiments with different agroecological methods to address climate change, food security, and social inequalities (Fig. 3). The Malawian NGO staff and volunteer Farmer Research Team members carried out monthly field visits to each participating village to observe changes. After twenty-four months of agroecological experiments, which included 2 rainy season cropping seasons and 2 seasons of dry season vegetable gardens, a final survey ( $n = 352$ ) was conducted in 2013 (t2) to assess changes in food security and dietary diversity over time, as well as the overall impacts of the project. The final survey repeated the same questions from the baseline, as well as questions about tree planting, knowledge generation and sharing, crop storage and how long household harvests lasted. Similar to the baseline survey, the final survey questions were written in English, translated into local languages and administered by trained enumerators to the same households in the baseline survey. Some households had dropped out of the study or could not be located ( $n = 103$ ), so a total of  $n = 203$  households were matched between the baseline and endline surveys for the longitudinal multivariate analysis. A total of 125 households were drawn from the northern site and 78 from the central site.

For the baseline and final surveys, two outcome variables were explored, food security and dietary diversity. Our main goal was to assess changes in these two variables over time, and whether these changes were attributed to the agroecological experiments or other factors. Food security status was measured using the Household Food Insecurity Access Scale (HFIAS), which consists of 9 standardized questions about different dimensions of food insecurity, including availability, access and utilization, asking about the quantity of food intake, quality of food, and anxiety about food access. The HFIAS questionnaire has been validated in sub-Saharan Africa (Coates et al., 2007; Maxwell et al., 2014) and used in several assessments of food security (e.g., M'Kaibi et al., 2015; Atuoye and Luginaah, 2017; Chakona and Shackleton, 2017). The scale can be used to divide households into four different food security categories: 1-food secure, 2-mildly food insecure, 3-moderately food insecure, and 4-severely food insecure. In this analysis, households that were food secure were coded as 1, whereas those who were mildly food insecure, moderately food insecure and severely food insecure were grouped together and coded



Fig. 1. Study site locations.

as 0, giving us a binary outcome variable.

We generated a Household Dietary Diversity Score (HDDS) based upon the presence of 16 food groups from a 24-hour dietary recall, adapted from Swindale and Bilinsky (2006) and modified to suit local Malawian diets. The household dietary diversity score had a minimum of 0 and a maximum 15. We classified households as having a medium dietary diversity if members consumed at least four different food crops ( $DDS \geq 4$ ), similar to other studies (Faber et al., 2009; Swindale and Bilinsky, 2006; Verger et al., 2019). Consequently, all households that had a score below four ( $DDS < 4$ ) were categorized as 0, and those with a score of four or more were categorized as 1 (Labadarios et al., 2011; Verger et al., 2019).

The following variables were used as factors for change in food security and nutrition: legume residue use, cropping pattern, crop diversity, land area under legumes, crop storage, discussion of farming

with spouse, information from climate change experiments and compost or manure use. Legume residue use was examined because it was one of the most common methods chosen by a majority of households and because previous research had shown it as a significant correlate of nutrition (Bezner Kerr et al., 2010; Nyantakyi-Frimpong et al., 2017). This response was coded as a binary, (0) for those who did not use legume crop residues, and (1) for those who used legume residues. Crop diversity, legume production and intercropping are all agroecological practices which have been shown to have positive impacts on ecosystem services such as biological nitrogen fixation, yield and reduction of pest and disease incidence (Kremen and Miles, 2012; Snapp et al., 2010). The cropping pattern was grouped into (1) sole maize, (2) maize and one legume, (3) maize and two legumes, and (4) two or more cereals together with two or more legumes. Number of fields planted was categorized into three groups: those who planted a single field as 1,



### Legend

- A:** Isabel Chirwa's Farm - Maize intercropped with *Gliricidia*, a nitrogen-fixing tree.
- B:** Sorghum, an indigenous drought-tolerant grain for crop diversification.
- C:** Cowpeas, for crop diversification and soil nitrogen fixation.
- D:** Pigs, for integrated crop-livestock systems, provide income, manure and buffer against crop failure.
- E:** Cereal-legume intercropping for nitrogen fixation and dietary diversity.
- F:** Jessie Kaunda's Farm - Doubled-up legume intercropping for crop diversification and soil improvement.
- G:** Fuel-efficient stove made of clay, which reduces firewood dependence and forest depletion.

Fig. 2. Examples of Agroecological Experiments.

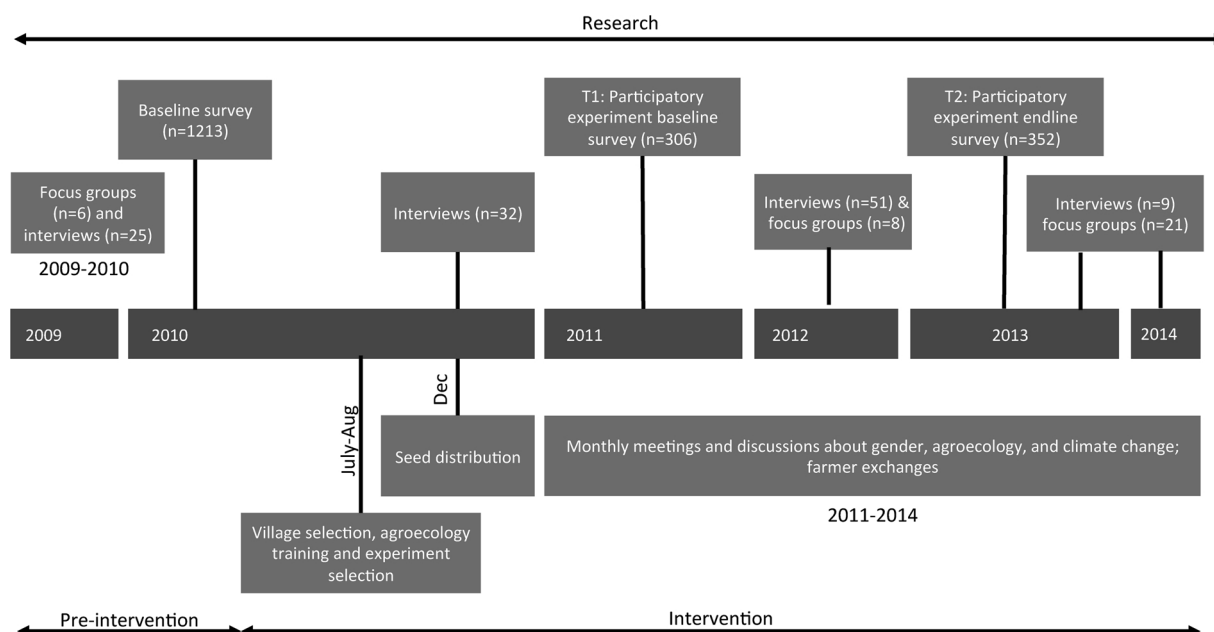


Fig. 3. Timeline of Research and Intervention Activities.

those who planted two fields as 2, and those who planted three fields and more as 3 + . The following variables were used as binaries with the categories (0) as No and (1) as Yes: storage of crops in past year, discussion of farming with spouse, use of information learnt from the climate change experiments, and the use of compost or manure to enhance soil fertility. The word ‘manure’ in local languages is used to mean compost, manure and composted manure. There is no separate word for compost. Educational background of participants was coded as 0 = No education, 1 = Primary, and 2 = Secondary and higher. Reported wealth levels were divided into five categories based on reported asset, a method validated in Africa (Morris et al., 2000). Study location was grouped into (1) Ekwendeni and (2) Kasungu. In predicting changes in dietary diversity, the following binaries were added. First, cropping patterns was grouped into (1) monocropping and (2) intercropping of maize and legumes. Marital status was categorized into (1) unmarried (including divorced, single and widowed) and (2) married. Finally, time (which is in years) was coded as (t1) 2011, and (t2) 2013.

### 2.3. Qualitative data collection

During and after the experiments, the research team also conducted in-depth interviews, focus groups and participant observation in order to better understand farmers’ own experiences with these agroecological methods. A total of 81 interviews and 29 focus groups were conducted (Table 1).

Interviews and focus group participants were selected using maximum variation sampling (Miles et al., 2014) in order to obtain a wide range of perspectives based on age, gender, HIV status, type of agroecological experiment and village location. The focus groups and interviews were conducted in Chitumbuka or Chichewa, the native

languages of people in the study areas. Field notes were taken during the interviews and focus groups. All research activities, including interviews, farm experiments, surveys and focus groups, were approved by the Non-Medical Research Ethics Board (NMREB) at Western University, Canada. Oral informed consent was obtained before conducting surveys, interviews, focus groups and participant observations. We obtained oral consent due to limited literacy levels of many participants.

### 2.4. Data analysis

The statistical analysis involved a descriptive comparison of the data between t1 and t2, as well as bivariate and multivariate analyses. A Pearson chi-square test of independence and Cramer’s V statistics were performed to examine the relationship between time (t1 and t2) and the characteristics of the respondents.

To estimate change over time within the individual farmers’ experiments, a longitudinal mixed effect logistic regression is appropriate (Rabe-Hesketh and Skrondal, 2005; Singer and Willet, 2003) for representing the change each individual is expected to experience from 2011 to 2013. Longitudinal mixed effects models were fitted for the two outcome variables while assessing the effect of agroecological factors and controlling for compositional factors and time in a nested model. This approach allowed us to specify how the average level of each of the response variable (food security and wealth) changes from t1 to t2 (over time), while allowing us to control for time varying (e.g., changes in agricultural practices) and time invariant (e.g., sex) covariates. (Singer and Willet, 2003; Cui, 2007; Liang and Zeger, 1986). The models were developed based on bivariate significance and theoretical relevance. Three multivariate models were fitted to each outcome variable. In model 1 we controlled for time and agroecological variables such as using compost. In model 2 introduced other agricultural variables such as discussing farming with spouse. In the final model 3 we controlled for socioeconomic and demographic variables. The *mecloglog* and *xtmelogit* commands available in Stata 13 were used to build the bivariate and multivariable models, with a logit and complementary log-log link, to account for the distribution of the key explanatory variables. Models were considered significant at four levels –  $p \leq 0.1$ ,  $p \leq 0.05$ ,  $p \leq 0.01$ , and  $p \leq 0.001$ .

The qualitative data, including transcripts and field notes, were

Table 1  
Qualitative research carried out. 2011–2014.

Year	In-depth interviews	Focus group discussions
2011	30	0
2012	51	8
2013	4	15
2014	5	6
<b>Total</b>	<b>90</b>	<b>29</b>

analyzed inductively for key themes to contextualize, to facilitate the triangulation of results (Creswell and Plano Clark, 2011). Two of the authors analyzed all the qualitative data. In order to strengthen the rigor and validity of the qualitative findings (Miles et al., 2014), several versions of the study results were shared at feedback workshops with Farmer Research Team (FRTs) leaders who facilitated the agroecological experiments at the village level. Important from a data quality and participatory methods perspective, the feedback and responses from these workshops helped focus analytical strategies and provided validation of the results.

### 3. Results

The results are organized under three broad themes: (1) general household characteristics; (2) changes in food security, dietary diversity and farming practices overtime; and (3) factors explaining changes in food security, dietary diversity and community relations. Where appropriate, we use farmer narratives to contextualize the statistical results.

#### 3.1. General household characteristics

Overall, the average household size was 5.6 in the 2011 baseline survey, and 5.9 in 2013 final survey. In both the baseline and final surveys, more than half (60.7% and 57.4% respectively) of the respondents were women. Male respondents had a mean age of 45 years, whereas female respondents had a mean age of 49 years. In both survey years, the majority of the participants had either some primary education, or completed primary school. There was no significant difference between the educational status of respondents from the north and central sites. There was a significant difference in the educational attainment of female respondents compared to male respondents. The majority of the women had lower levels of primary education compared to men in both the 2011 and 2013 survey years.

The respondents reported several income sources, including farming, *ganyu* (casual farm labour), small businesses, selling firewood and beer brewing. Among these activities, farming emerged as the most dominant source of income, reported by 59% of the 2011 sample, and 70% of the 2013 sample. About 15% of respondents in the 2011 sample indicated that they derived incomes from *ganyu*, but only 10% of the 2013 respondents reported *ganyu* as a source of income. In the 2011 survey, households' total agricultural fields was on average 3.03 ha, while the final survey revealed a statistically significant increase in average area under cultivation (4.09 ha), with a range of 0–21 ha.

The chi-square test showed a statistically significant relationship ( $p < 0.05$ ) between respondents' characteristics and the two time periods. However, in all of the cases, the strength of the association was very weak; from Table 2, Cramer's  $V < 0.3$ , with the exception of study location region, crop diversity, the use of crop residue to enhance soil fertility, number of fields planted, and income levels. Another chi-square test of independence of food security was calculated using the reported frequencies of agroecological experiments in survey data (which were triangulated with qualitative field observations) and respondent background characteristics. The chi-square statistic firmly fails to reject the hypothesis that the explanatory factors are independent of food security. Consequently, the independence of the explanatory variables is assumed.

#### 3.2. Changes in food security, dietary diversity farming methods and social relations

Table 2 shows the changes in food security, dietary diversity and key farming practices over the two survey periods. Food security exhibited an asymmetrical distribution (75.25%, 24.75%) while household dietary diversity exhibited symmetrical distribution (49.75%, 50.25%) making the complementary log-log and logit link functions

appropriate for estimating the population parameters respectively (Tabachnick and Fidell, 2007). In the 2011 baseline survey, only 21% of households were food secure, but the final survey recorded a significant change in the proportion of food security, albeit marginally at 90% CI, with an increase to 28% food secure households. Household dietary diversity also improved significantly. In the baseline survey, about 54% of households consumed diets made up of 4 or more food groups, but this figure increased to 67% of households in the 2013 survey. In terms of agroecological farming practices, the majority of farmers (65%) were incorporating legume crop residues into the soil in the 2013 survey, compared to 40% in the 2011 survey. Another important finding concerns social relations around farming decisions; in the final survey, more couples (28%) were discussing farming practices with their spouses, more than double the rate of what was recorded in the baseline survey (12%).

During in-depth interviews, participants were asked what changes (if any) were due to participation in the intervention. The most commonly referenced change was in the diversity of crops grown. Most farmers indicated that crop diversity was increased to improve harvest outcomes in cases of drought. Farmers described growing more legumes, indigenous grains such as sorghum and finger millet, sweet potatoes, dry season vegetable gardens (called *dimbas*), and in general relying less on maize as their primary food crop.

The findings revealed changes in crop diversity: there were 2.5 different crops per ha in 2011, and 3 crops per ha in 2013. Similarly, there were 3.4 crops per farm in 2011 and 4.1 crops per farm in 2013. The final survey revealed an increase in the number of fields with legumes, specifically pigeonpea (*Cajanus cajan*), soya beans (*Glycine max*) and groundnuts (*Arachis hypogaea*), compared to the baseline. In the 2013 survey, significantly more households cultivated indigenous crops such as sorghum (*Sorghum bicolor*) (45%) and cowpea (*Vigna unguiculata*) (15%) (Table 3). The survey findings also show a significant decrease in the percentage of households which cultivated tobacco (19%) in the 2013 survey, compared to 53% in the baseline.

Cropping patterns changed significantly in this 2-year period (Table 4). A significant percentage of households had put their fields under legume cultivation (46%) compared to 31% in the baseline survey. There was a dramatic increase in intercropping: 29% percent of households intercropped in 2011, compared to a 93% of households in 2013. The most common intercrops were maize-cowpea, maize-groundnut, and maize-cowpea-groundnuts.

In the 2011 and 2013 surveys, we also asked farmers whether they cultivate crops in a *dimba*, a dry season vegetable garden. We found that *dimba* cultivation increased significantly from 54% of households in 2011, to 61% of households in 2013. Crop diversity within *dimbas* also increased, from an average of 1.2 crops in 2011 to 2.5 crops per *dimba* in 2013. A forty-two-year old female farmer narrated her experience by saying:

"We've increased *dimba* cultivation because of experiences from the climate change experiments. The best I like is intercropping and making use of your own crop residues. We now intercrop different crops, we use manure, and we bury our crop residues in the soils. Since we started using these simple strategies, we've seen significant changes in our *dimbas*. Even in the dry season, we're able to increase maize and vegetable yields without using fertilizer. It's a pleasant feeling to see the impacts of such little techniques." [Field Interview, August 2013]

Another change frequently mentioned by farmers was livestock holdings, namely pigs and goats, since integration of small livestock into the farming system was one of the agroecological 'experiments'. The livestock provided both manure for soil improvement as well as a source of income to cash-strapped farming households, as one participating woman farmer described:

"I consider this climate change program very beneficial to me. What

**Table 2**  
Distribution of variables by time (n = 203 respondents).

Variables	Baseline survey -T1 (2011) (%)	Final Survey-T2 (2013) (%)	Pearson's $\chi^2$ (df)
<b>Food Security</b>			$\chi^2$ (1) = 2.42 P = 0.120 Cramer's V = 0.077
No	78.61	71.92	
Yes	21.39	28.08	
<b>Household Dietary Diversity Score</b>			$\chi^2$ (1) = 6.89 P = 0.009 Cramer's V = 0.1307
0-3	45.77	33.00	
4+	54.23	67.00	
<b>Practice Legume Crop Residue Incorporation</b>			$\chi^2$ (1) = 25.76 P = 0.000 Cramer's V = 0.4469
No	60.20	34.98	
Yes	39.80	65.02	
<b>Number of Fields Planted</b>			$\chi^2$ (2) = 2.55 P = 0.279 Cramer's V = 0.3605
1	20.40	17.73	
2	48.26	43.35	
3+	31.34	38.92	
<b>Stored Crop in Past Year</b>			$\chi^2$ (1) = 13.86 P = 0.000 Cramer's V = -0.0916
No	9.45	23.14	
Yes	90.55	76.85	
<b>Discuss Farming with Spouse</b>			$\chi^2$ (1) = 14.45 P = 0.000 Cramer's V = -0.1306
No	87.56	72.41	
Yes	12.44	27.59	
<b>Use Information Learnt from the Climate Change Project</b>			$\chi^2$ (1) = 31.79 P = 0.000 Cramer's V = 0.1690
No	36.32	26.60	
Yes	42.79	26.11	
	20.90	47.29	
<b>Use Compost or Manure for Soil Fertility</b>			$\chi^2$ (1) = 5.23 P = 0.022 Cramer's V = 0.1094
No	52.24	40.89	
Yes	47.76	59.11	
<b>Education</b>			$\chi^2$ (2) = 1.474 P = 0.478 Cramer's V = 0.0667
None	6.97	5.91	
Primary	78.61	83.25	
Secondary +	14.43	10.84	
<b>Wealth</b>			$\chi^2$ (4) = 5.46 P = 0.243 Cramer's V = 0.1163
Very poor	23.88	31.53	
Poor	16.42	10.84	
Middle	20.40	22.66	
Better off	19.40	15.76	
Richer	19.90	19.21	
<b>Marital Status</b>			$\chi^2$ (1) = 0.1689 P = 0.681 Cramer's V = 0.0809
Unmarried	23.38	21.67	
Married	76.62	78.33	

**Table 3**  
Proportion of households planting crops on farm in 2011 and 2013.

Crop	Time 1 (2011, n = 306) (%)	Time 2 (2013, n = 352) (%)
Bambara Nuts	4	5
Cassava	25	24
Beans	48	57*
Cowpea	7	15*
Groundnuts	70	61
Maize	100	100
Millet	10	14
Pigeon Pea	8	32**
Pumpkins	12	6**
Sorghum	3	45**
Soya Beans	62	71*
Sweet Potatoes	25	30
Tobacco	53	19**

\* p ≤ 0.1.

\*\* p ≤ 0.05.

makes me happy is that I received a pig from the project in 2011. At first the pig had 8 offspring, which I gave to my fellow climate change participants in my village, and this year it also had 6 offspring, which I have planned to sell when they are weaned, and with this [money] I hope that I will improve my home even more. When I sell the younger pigs I will buy some goats. My future plans are that I want to buy some iron sheets [for the roof] with money from the sales of the pigs." [Field Interview, August 2013].

After four years we measured a significant increase in families

**Table 4**  
Proportion of rainfed fields under different crop groups in 2011 and 2013.

Variable	Time 1 (2011, n = 306) (%)	Time 2 (2013, n = 352) (%)
Proportion of households using intercropping (%)	29	93
<i>Proportion of fields under legumes, cereals and tubers (%)</i>		
Legumes	31	46
Cereals	53	43
Tubers	10	9
Other crops	6	2
<i>Proportion of fields under 1 crop, 2 crops, and 3+ crops (%)</i>		
1 crop	42	19
2 crops	31	42
3+ crops	27	39

managing small herds of livestock. Twenty-five pigs and 21 goats were purchased to establish community livestock pens in year two of the four-year project. Over 100 pigs and goats were produced in village livestock pens and distributed to participating farmers. A total increase of 44 percent in animal ownership was reported in the final survey.

Several impacts on soil management were observed and measured during the four-year project. There was a significant increase in the number of households using soil improvement strategies (Table 5). Compost and manure use and incorporating crop residue were the two most common strategies used to improve soil fertility, while contour bands and vetiver grass were the most common soil conservation practices. There was an 11 percent increase in households using

**Table 5**  
Different soil management strategies used in 2011 and 2013.

Soil management strategy	Time 1 (2011, n = 306) (%)	Time 2 (2013, n = 352) (%)
Compost/manure	47.75	58.95 <sup>*</sup>
Incorporate crop residue	41.3	54.4 <sup>*</sup>
Use contour bands	36.3	32.35 <sup>**</sup>
Plant vetiver grass	33.25	32.8 <sup>*</sup>
Use box ridge	26.2	28.7 <sup>**</sup>
Agroforestry	18.35	20.45 <sup>***</sup>
Sunken beds	3.1	5.65 <sup>*</sup>
Zero tillage	2.15	1.65 <sup>*</sup>

\*  $p \leq 0.1$ .

\*\*  $p \leq 0.05$ .

\*\*\*  $p \leq 0.01$ .

compost or manure, and a 13 percent increase in households using crop residue. In interviews new animal-holding families reported that they had begun applying animal manures in a targeted manner, focused on planting ridges in order to maximize the benefit of limited compost and manure resources. Farmers with previous animal experience reported an increase in the application of manure to cultivated fields, and application changed from a generalized broadcast to a concentrated application on planting ridges.

There was also an increase in the use of legume residue incorporation into the soils after harvest, as a means to improve soil fertility. While this strategy had been tested by members of the research team in previous research projects in the northern site (Bezner Kerr et al., 2007; Snapp et al., 2010), it was new for many participating households. The link between improved soil fertility and crop response during droughts was also new, and one that farmers stressed. One farmer for example, experimented with the double legume intercrops of pigeonpea and soya/groundnut in his fields and noted:

“These legumes make a big difference in the soils. Water is held in the soils, it soaks in more easily and soil is not as easily washed away. The groundnut and pigeonpea residue helps improve the strength of the soil.” (Field Interview, February 4, 2014).

Agroforestry was another experiment type; several village nurseries were started and maintained by participants. The majority of participating farmers (82%) reported planting new trees on their homestead, and we observed increased agroforestry plantings, including *Acacia albida* and *Gliricidia*. Fruit trees were also planted by individual farmers, including mango, guava and orange. There was a 9% increase in the number of farming households who reported planting *Acacia albida* to improve soil fertility.

While some of these strategies (e.g. applying livestock manure, planting trees) are not new in these communities, linking these methods to climate change adaptation was a novel idea for most participating farmers. Some participating farmers who had previously kept livestock but not applied the manure to soils, began to apply the manure, indicating that they were motivated by the idea of improving soil quality in case of drought.

In interviews and focus groups, participating farmers reported significant improvements in household and community relations. For example, in describing general improvements in soil health and dietary diversity, farmers often interlaced these accounts with comments on improved decision-making between spouses or in communities:

“There is a lot of change because now I have enough food through growing legumes. My family is healthy and we have a strong relationship. We have managed to improve our soils and the community also seems to have improved relations.” [Male farmer, Married, Age 34 – Interviewed July 30, 2013].

“We have really improved our soils because where we grew the legumes, maize do better and we have enough food for now. My

family’s health has also improved for the better and so are our relations.” [Female farmer, Married, Age 44 – Interviewed July 30, 2013].

I used to grow only maize at first but now with the climate change project I am able to grow lots of legumes which have improved my soil, increased my food and have helped improve my family relations. [Male farmer, Married, Age 30 – Interviewed July 31, 2013].

“My family is very healthy because we eat a variety of foods – groundnuts, soya beans, sorghum, cassava. My soils have improved looking at the soil colour, dark. Soya beans, groundnut when incorporated [into soils] they improve soils. My wife and I make decisions on what type of crops to be grown, how to use the money after crop sales.” [Male farmer, Married, Age 28 – Interviewed July 26, 2013].

In a related paper, we report on the ways in which agricultural knowledge flows within households and communities were significantly altered with the project’s participatory research approach (Bezner Kerr et al., 2018). The majority of farmers reported learning new information about farming, experimenting with new approaches and sharing their findings with family and community members. These qualitative findings shed light on the quantitative relationships we discuss below.

### 3.3. Determinants of improved food security and dietary diversity

The multivariate results for each outcome variable are presented in Tables 6 and 7 respectively. Model 1 examines the effect of year of study, crop residue incorporation, proportion of land planted with legumes, and farm size cultivated. Model 2 examines the effect of model 1 while controlling for crop diversity and other farming practices including: the use of compost/manure, storage of crops in the past year, discussion of farming with spouse, and the use of climate change information learned from the project. Model 3 includes demographic factors such as: district of residence, marital status, age, level of education, and asset level.

In Model 1 of Table 6, the results show no significant association between food security and any of the explanatory variables. In Model 2 however, an increase in farm size is associated with higher likelihood of improved food security. Also, farmers who cultivate 5–6 fields were more likely to report improved food security compared to farmers that cultivated only one or two fields during the farming season. Farmers who discuss farming with their spouse were more likely to report an improvement in food security compared to those that did not. Similarly, the result show that receiving information on climate change is associated with improvements in food security, even though only the “sometimes” category was significant. In Model 3, after including demographic factors, the significant effect of land size on food security remained, whilst number of fields planted remain robust. Discussing farming with spouse remained a robust correlate of improvement in food security. Farmers were significantly more likely to be food secure if they belong to the highest asset quintile (OR = 2.50,  $p = 0.05$ ) compared to those in the lowest asset quintile.

Table 7 presents three models showing determinants of change in household dietary diversity. The results show that farmers in 2013 (OR = 1.58,  $p = 0.05$ ) were more likely to report improvement in dietary diversity compared to 2011. Farmers who practiced crop residue incorporation were also more likely to have an improvement in household dietary diversity compared to those that did not. In model 2 after controlling for other agricultural variables, however, the association between dietary diversity and time disappeared. Only total land farmed and manure or compost application was associated with changes in dietary diversity. An increase in total land farmed (OR = 1.12,  $p = 0.10$ ) was associated with higher likelihood of improvement in dietary diversity. Farmers who apply manure or compost

**Table 6**  
Multivariate determinants of change in food security.

Independent Variables	Model (1)	Model (2)	Model (3)
Year of Survey (ref: 2011)			
2013	1.31(0.280)	1.04(0.486)	1.35(0.668)
Incorporating crop residue into soil (ref: no)			
Yes	1.32(0.302)	1.09(0.297)	0.98(0.283)
Proportion of land planted with legumes	1.01(0.003)	1.01(0.004)	1.006(0.004)
Total land farmed in acres		1.14(0.063)**	1.12(0.068)*
Number of fields planted (1/2)			
3-4		1.33(0.549)	1.34(0.575)
5-6		2.53(1.102)**	2.47(1.136)**
Cropping pattern (ref: Grains monocrop)			
Grains and legumes		1.37(0.552)	1.37(0.581)
Grains, legumes and tuber		1.18(0.572)	1.03(0.520)
Grains, legumes, tubers and cash crops		2.18(1.256)	1.82(1.116)
Grains, legumes, tubers, cash crops and fruits		1.75(1.043)	1.17(0.762)
Total number of crops planted		0.99(0.066)	0.98(0.068)
Did you store crops after harvesting (ref: no)			
Yes		1.33(0.492)	1.17(0.473)
Discuss farming with spouse (ref: No)			
Yes		2.44(0.850)**	2.47(0.897)**
Received information on climate change (ref: never)			
sometimes		1.72(0.544)*	1.50(0.505)
often		1.58(0.525)	1.42(0.497)
Apply manure (ref: no)			
Yes		1.07(0.285)	1.08(0.303)
Fertilizer soil			
Yes		0.97(0.263)	0.88(0.257)
District of residence			
Kasungu			0.74(0.235)
Marital status (ref: not currently married)			
Currently married			0.85(0.324)
Age			0.99(0.0118)
Educational level (ref: none)			
Primary			1.45(0.971)
Secondary and Tertiary			1.85(1.371)
Wealth indices (ref: Very poor)			
Poor			1.04(0.474)
Middle			0.79(0.333)
Better off			1.16(0.487)
Richer			2.50(1.042)**
Variance	1.64(0.602)	2.04(1.017)	2.34(1.423)
Constant	0.15(0.045)***	0.012(0.010)***	0.017(0.022)***
Observations	406	406	406
Number of groups	203	203	203

Notes: OR = Odds Ratio; (Ref.) = Reference Categories. Numbers in parenthesis are standard errors.

\*  $p \leq 0.1$ .

\*\*  $p \leq 0.05$ .

\*\*\*  $p \leq 0.01$ .

(OR = 1.58,  $p = 0.10$ ) were more likely to report improvement in dietary diversity compared to those who do not. After controlling for all demographic factors and wealth, the association between dietary diversity and manure or compost applicant remained significant.

#### 4. Discussion and conclusion

This study provides evidence that policies and programs that support farmers to test agroecological methods, combined with

**Table 7**  
Multivariate determinants of change in household dietary diversity.

Independent Variables	Model (1)	Model (2)	Model (3)
Year of Survey (ref: 2011)			
2013	1.58(0.223)**	1.199(0.527)	1.56(0.749)
Incorporating crop residue into soil (ref: no)			
Yes	1.62(0.229)***	1.202(0.297)	1.12(0.294)
Proportion of land dedicated for legume	0.99(0.004)	0.99(0.004)	1.00(0.004)
Total land farmed in acres		1.12(0.0778)*	1.08(0.081)
Number of fields planted(ref: 1/2)			
3-4		1.31(0.409)	1.30(0.435)
5-6		1.59(0.585)	1.64(0.642)
Cropping pattern (ref: Grains monocropped)			
Grains and legumes		1.53(0.547)	1.65(0.648)
Grains, legumes and tuber		1.38(0.622)	1.19(0.581)
Grains, legumes, tubers and cash crops		1.90(1.032)	1.43(0.857)
Grains, legumes, tubers, cash crops and fruits		1.76(1.035)	1.16(0.753)
Total number of crops planted		0.97(0.064)	0.98(0.067)
Did you store crops after harvesting (ref: no)			
Yes		1.04(0.326)	0.83(0.286)
Discuss farming with spouse (ref: Yes)			
No		0.81(0.243)	0.82(0.265)
Received information on climate change (ref: never)			
sometimes		1.25(0.346)	1.21(0.361)
often		0.89(0.265)	0.81(0.261)
Apply compost/manure (ref: no)			
Yes		1.58(0.393)*	1.71(0.454)**
Fertilizer soil			
Yes			0.87(0.245)
District of residence			
Kasungu			0.71(0.209)
Marital status (ref: not currently married)			
Currently married			1.46(0.495)
Age			0.99(0.0103)
Educational level (ref: none)			
Primary			0.76(0.369)
Secondary and Tertiary			0.82(0.495)
Wealth indices (ref: Very poor)			
Poor			0.83(0.329)
Middle			0.84(0.302)
Better off			1.51(0.599)
Richer			1.75(0.735)
variance	0.68(0.309)	0.46(0.437)	0.51(0.427)
Constant	0.97(0.242)	0.36(0.205)*	0.41(0.383)
Observations	404	404	404
Number of groups	203	203	203

Notes: OR = Odds Ratio; (Ref.) = Reference Categories. Numbers in parenthesis are standard errors.

\*  $p \leq 0.1$ .

\*\*  $p \leq 0.05$ .

\*\*\*  $p \leq 0.01$ .

community-based education on gender equity, can significantly improve food security and nutrition for highly vulnerable rural smallholder households in Malawi. Although the lack of control households in this study is a significant limitation, the quantitative results were supported by qualitative field observations and in-depth interviews. Further, there is need for detailed case studies such as this one that addresses mixed maize smallholder systems. Across Africa these systems represent a large proportion of people in poverty (Blackie and

Dixon, 2016).

Incorporation of organic materials was significantly correlated with food security and dietary diversity in our multivariate analysis. This strategy for climate change adaptation is consistent with recent calls by Noiret (2016) as a means to build resilience of smallholder farming systems. Diversified farming systems, including small livestock and legumes, are keys to farmer utilizing agroecological principles, supporting the experimentation with and use of strategies for biological renewal of soils, for control of pests and buffering against extreme events. Legumes are important components of organic soil management and sustainable agriculture, as they support biological processes that enhance soil nitrogen without reliance on fossil fuels (Gliessman, 2015). In Malawi, diversification of agriculture with legumes such as pigeonpea has been shown to improve soil phosphorus and nitrogen availability (Garland et al., 2018). In turn, organic soil amendment had significant impacts on both food security and dietary diversity. Previous studies in Malawi indicated that legume diversification combined with community-based education on gender and nutrition is positively related to child nutrition, ecosystem services such as soil cover, as well as providing profitable farm options (Bezner Kerr et al., 2010; Snapp et al., 2010).

One significant dimension of this study is that the households were selected based on their high levels of food insecurity and/or presence of someone with HIV/AIDS in the household. The study also included community-based education on gender and other social inequalities. The findings demonstrate that through participatory action research methods, highly vulnerable food insecure households, including those who are AIDS-affected, can use agroecological methods to address their food security and diet quality, with important implications for agricultural policies in Sub-Saharan Africa.

Another novel and important finding of this study was that households in which spouses discussed farming strategies were 2.4 times more likely to have improved food security and dietary diversity, stressing the importance of attention to gender inequality and knowledge sharing at multiple scales. These research findings support the need for attention to gender and other equity issues raised by other studies critical of standard sustainable intensification approaches (Chappell et al., 2013; Loos et al., 2014).

Crop diversification has been previously shown to be an important strategy for building resilience in food systems to changing climates (Lin, 2011). In Malawi households that cultivate a diverse range of crops are also more likely to have greater dietary diversity, which is a key measure of improved nutrition (Jones et al., 2014). Previous research in Malawi has indicated that a farmer's decision to increase legume cultivation can be influenced by labor requirements, seed access, market potential and multi-purpose uses, with gender roles and income level playing a mediating role (Waldman et al., 2016; Bezner Kerr et al., 2007; Snapp et al., 2002). Farmer observations about their diets and farming practices suggested that crop diversification was a key strategy for them to adapt to climate change as well as improve diets. In multivariate analysis, discussing farming with spouse, and soil amendment with organic materials (crop residue, compost) were more significant strategies linked to food security and dietary diversity. While crop diversity did not show statistical significance, in qualitative interviews farmers observed that the additional crops reduced the period of food shortages in their homes, provided additional income and increased the range of types of foods eaten.

Farmers also significantly increased intercropping, both with legumes and other crops. A study in Mozambique comparing intercropped legume systems with monocrops under smallholder conditions found that intercropping increased yields and incomes, and led to higher rainfall infiltration and greater resilience under unpredictable rainfall conditions (Rusinamhodzi et al., 2012). Farmers in this study also spoke of the improved soil quality and ability to withstand dry spells as an important reason for intercropping. Other studies in eastern Africa have also found intercropping, compost and manure use to be

positively associated with food security (Kristjanson et al., 2012).

This study contrasts with previous reviews, which have suggested that agroecological, diversified farming systems may reduce crop productivity relative to conventional farming systems (Ponisio et al., 2015; Seufert et al., 2012). Importantly, the farming households selected for this study were highly food insecure, and participatory research methods were used such that farmers selected and tested a range of agroecological practices suitable to their available labor and resources. Other studies looking at the relationship between food security and farmer innovation in eastern Africa found a negative relationship between farmer innovation (measured through a range of farming practices) and food insecurity (Kristjanson et al., 2012). Several studies have advocated for more specific policy measures to ensure that highly food insecure and poor households are targeted in agricultural interventions (Barrett et al., 2006; Conceição et al., 2016; Kristjanson et al., 2012). Our study suggests that when such households are specifically selected and carry out their own experiments using agroecological methods, they can make significant changes to their food security and diets. While making changes to food insecurity and diets within 2 years is a significant finding, further study is needed to know what support highly vulnerable households need to sustain these changes in food security and nutrition. Future studies should include control households or delayed intervention designs—as calls for more rigorous research designs in agriculture-nutrition studies have noted (Masset et al., 2012)—to fully substantiate these results.

There have been recent calls to integrate nutritional, environmental and economic outcomes in addressing food security and nutrition (Herforth et al., 2015; Noiret, 2016; Schipanski et al., 2016). Several recent high-level reports have highlighted agroecology and participatory research as having strong potential to address environmental, equity and food security goals in light of climate change (De Schutter, 2010; IPES-Food, 2016). Our findings suggest that agroecological methods employed by food insecure farmers themselves, with attention to gender and other social inequalities, can have significant impacts on food security and nutrition while using environmentally sustainable management methods.

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## References

- Aberman, N.-L., Rawat, R., Drimie, S., Claros, J.M., Kadiyala, S., 2014. Food security and nutrition interventions in response to the aids epidemic: assessing global action and evidence. *AIDS Behav.* 18, 554–565. <https://doi.org/10.1007/s10461-014-0822-z>.
- Atuoye, K.N., Luginaah, I., 2017. Food as a social determinant of mental health among household heads in the Upper West Region of Ghana. *Soc. Sci. Med.* 180 (C), 170–180.
- Barrett, C.B., Marenya, P.P., Mcpeak, J., Minten, B., Murithi, F., Oluoch-Kosura, W., Place, F., Randrianarisoa, J.C., Rasambainarivo, J., Wangila, J., 2006. Welfare dynamics in rural Kenya and Madagascar. *J. Dev. Stud.* 42, 248–277. <https://doi.org/10.1080/00220380500405394>.

- Bezner Kerr, R., 2012. Lessons from the old Green Revolution for the new: social, environmental and nutritional issues for agricultural change in Africa. *Prog. Dev. Stud.* 12, 213–229. <https://doi.org/10.1177/146499341101200308>.
- Bezner Kerr, R., Snapp, S.S., Chirwa, M., Shumba, L., Msachi, R., 2007. Participatory research on legume diversification with Malawian smallholder farmers for improved human nutrition and soil fertility. *Exp. Agric.* 43, 437–453. <https://doi.org/10.1017/S0014479707005339>.
- Bezner Kerr, R., Berti, P.R., Shumba, L., 2010. Effects of participatory agriculture and nutrition project on child growth in Northern Malawi. *Public Health Nutr.* 14 (8), 1466–1472. <https://doi.org/10.1017/S1368980010002545>.
- Bezner Kerr, R., Chilanga, E., Nyantakyi-Frimpong, H., Luginaah, I., Lupafya, E., 2016a. Integrated agriculture programs to address malnutrition in northern Malawi. *BMC Public Health* 16, 1197. <https://doi.org/10.1186/s12889-016-3840-0>.
- Bezner Kerr, R., Lupafya, E., Shumba, L., Dakishoni, L., Msachi, R., Chitaya, A., Nkhonjera, P., Mkandawire, M., Gondwe, T., Maona, E., 2016b. “Doing Jenda deliberately” in a participatory agriculture and nutrition project in Malawi. In: Njuku, J., Kaler, A., Parkins, J. (Eds.), *Transforming Gender and Food Security in the Global South*. Routledge, London, pp. 241–259.
- Bezner Kerr, R., Nyantakyi-Frimpong, H., Dakishoni, L., Lupafya, E., Shumba, L., Luginaah, I., Snapp, S.S., 2018. Knowledge politics in participatory climate change adaptation research on agroecology in Malawi. *Renewal Agriculture and Food Systems* 33, 238–251. <https://doi.org/10.1017/S1742170518000017>.
- Bezner Kerr, R., Owoputi, I., Rahmanian, M., Batello, C., 2019. Agroecology and nutrition: transformative possibilities and challenges. In: Burlingame, B., Dernini, S. (Eds.), *Sustainable Diets*. CABI, Wallingford, pp. 53–63.
- Blackie, M., Dixon, J., 2016. Maize mixed farming systems: an engine for rural growth. In: Dixon, J., Garrity, D., Boffa, J.M., Williams, T., Amede, T., Auricht, C., Lott, R., Mburathi, G. (Eds.), *Farming Systems and Food Security in Africa: Priorities for Science and Policy Under Global Change*. Routledge, London and New York, USA.
- Bryceson, D.F., Fonseca, J., 2006. Risking death for survival: peasant responses to hunger and HIV/AIDS in Malawi. *World Dev.* 34, 1654–1666. <https://doi.org/10.1016/j.worlddev.2006.01.007>.
- Carlson, G.J., Kordas, K., Murray-Kolb, L.E., 2015. Associations between women’s autonomy and child nutritional status: a review of the literature. *Matern. Child Nutr.* 11, 452–482.
- Chakona, G., Shackleton, C.M., 2017. Household food insecurity along an agro-ecological gradient influences children’s nutritional status in South Africa. *Front. Nutr.* 4, 72. <https://doi.org/10.3389/fnut.2017.00072>.
- Chappell, M., Wittman, H., Bacon, C., Ferguson, B.G., Garcia Barrios, L., Garcia Barrios, R., Jaffee, D., Lima, J., Mendez, V.E., Morales, H., Soto-Pinto, L., Vandermeer, J., Perfecto, I., 2013. Food sovereignty: an alternative paradigm for poverty reduction and biodiversity conservation in Latin America. *F1000Research* 2.
- Chirwa, E., Dorward, A., 2013. *Agricultural Input Subsidies: the Recent Malawi Experience*. Oxford University Press.
- Coates, J., Swindale, A., Bilinsky, P., 2007. Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide (V.3). Food and Nutrition Technical Assistance III Project (FANTA).
- Conceição, P., Levine, S., Lipton, M., Warren-Rodríguez, A., 2016. Toward a food secure future: ensuring food security for sustainable human development in Sub-Saharan Africa. *Food Policy* 60, 1–9. <https://doi.org/10.1016/j.foodpol.2016.02.003>.
- Creswell, J., Plano Clark, V., 2011. *Designing and Conducting Mixed Methods Research*. Sage Publications, Thousand Oaks, Calif.
- Cui, J., 2007. QIC: stata module to compute model selection criterion in GEE analyses. *Stata J.* 7, 209–220.
- De Schutter, O., 2010. Agroecology and the Right to Food. United Nations General Assembly, Human Rights Council 16th Session, Agenda Item 3, Reported Submitted by the Special Rapporteur on the Right to Food, UN A/HRC/16/49. United Nations General Assembly. <http://www.srfood.org/index.php/en/component/content/article/1174-report-agroecology-and-the-right-to-food>.
- Diaz, R.J., Rosenberg, R., 2008. Spreading dead zones and consequences for marine ecosystems. *Science* 321, 926–929. <https://doi.org/10.1126/science.1156401>.
- Dorward, A., Mwale, I., 2006. Labour Market and wage impacts of HIV/AIDS in rural Malawi. In: Gillespie, S.R. (Ed.), *AIDS, Poverty, and Hunger: Challenges and Responses*. International Food Policy Research Institute (IFPRI), Washington, DC.
- Dumont, A.M., Vanloqueren, G., Stassart, P.M., Baret, P.V., 2016. Clarifying the socio-economic dimensions of agroecology: between principles and practices. *Agroecol. Sustain. Food Syst.* 40, 24–47.
- Eastin, J., 2018. Climate change and gender equality in developing states. *World Dev.* 107, 289–305. <https://doi.org/10.1016/j.worlddev.2018.02.021>.
- Ecker, O., Qaim, M., 2011. Analyzing nutritional impacts of policies: an empirical study for Malawi. *World Dev.* 39, 412–428. <https://doi.org/10.1016/j.worlddev.2010.08.002>.
- Ericksen, P., Ingram, J., Liverman, D., 2009. Food security and global environmental change: emerging challenges. *Environ. Sci. Policy* 12, 373–377. <https://doi.org/10.1016/j.envsci.2009.04.007>.
- Faber, M., Schwabe, C., Drimie, S., 2009. Dietary diversity in relation to other household food security indicators. *Int. J. Food Saf. Nutr. Public Health* 2, 1–15. <https://doi.org/10.1504/IJFSNPH.2009.026915>.
- FAO, IFAD, UNICEF, WFP, WHO, 2017. *The State of Food Security and Nutrition in the World 2017. Building Resilience for Peace and Food Security*. FAO, Rome.
- FAO, IFAD, UNICEF, WFP, WHO, 2018. *The State of Food Security and Nutrition in the World 2018. Building Climate Resilience for Food Security and Nutrition*. FAO, Rome.
- Frison, E.A., Cherfas, J., Hodgkin, T., 2011. Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security. *Sustainability* 3 (1), 238–253. <https://doi.org/10.3390/su3010238>.
- Garland, G., Bünemann, K., Oberson, A., Frossard, E., Snapp, S., Chikowo, R., Six, J., 2018. Phosphorus cycling within soil aggregate fractions: a conceptual model. *Soil Biol. Biochem.* 116, 91–98.
- Gabriel, D., Sait, S.M., Hodgson, J.A., Schmutz, U., Kunin, W.E., Benton, T.G., 2010. Scale matters: the impact of organic farming on biodiversity at different spatial scales. *Ecology Letters* 13 (7), 858–869.
- Gliessman, S.R., 2015. *Agroecology: The Ecology of Sustainable Food Systems*, third edition. CRC Press.
- Godfray, H.C.J., Garnett, T., 2014. Food security and sustainable intensification. *Philos. Trans. Biol. Sci.* 369, 20120273. <https://doi.org/10.1098/rstb.2012.0273>.
- Goulson, D., Nicholls, E., Botías, C., Rotheray, E.L., 2015. Bee declines driven by combined stress from parasites, pesticides, and lack of flowers. *Science* 347, 1255957. <https://doi.org/10.1126/science.1255957>.
- Government of Malawi (GOM), 2014. *Global AIDS Response Progress Report: Malawi Progress Report for 2013*. Ministry of Health, Lilongwe.
- Haddad, L., 2013. From Nutrition plus to Nutrition Driven: How to Realize the Elusive Potential of Agriculture for Nutrition? *Food Nutr. Bull.* 34 (1), 39–44. <https://doi.org/10.1177/156482651303400105>.
- Hayes, N.C., 2016. “Marriage is perseverance”: structural violence, culture, and AIDS in Malawi. *Anthropologica* 58, 95–105.
- Hector, A., Bagchi, R., 2007. Biodiversity and ecosystem multifunctionality. *Nature* 448, 188–190. <https://doi.org/10.1038/nature05947>.
- Herforth, A., Liddle, P., Gill, M., 2015. Strengthening the links between nutrition and health outcomes and agricultural research. *Food Secur.* 7, 457–461. <https://doi.org/10.1007/s12571-015-0451-z>.
- Holt-Giménez, E., 2002. Measuring farmers’ agroecological resistance after Hurricane Mitch in Nicaragua: a case study in participatory, sustainable land management impact monitoring. *Agric. Ecosyst. Environ.* 93 [https://doi.org/10.1016/S0167-8809\(02\)00006-3](https://doi.org/10.1016/S0167-8809(02)00006-3), 1–3, 87–105.
- HLPE, 2017. *Nutrition and food systems. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security*. Rome. <http://www.fao.org/3/a-i7846e.pdf>.
- Hyder, A.A., Maman, S., Nyoni, J.E., Khasiani, S.A., Teoh, N., Premji, Z., Sohani, S., 2005. The pervasive triad of food security, gender inequity and women’s health: exploratory research from sub-Saharan Africa. *Afr. Health Sci.* 5 (4), 328–334.
- Intergovernmental Panel on Climate Change (IPCC), 2018. *Global Warming of 1.5 °C: Summary for Policymakers*. World Meteorological Organization, Geneva, Switzerland.
- IPES-Food, 2016. *From Uniformity to Diversity: a Paradigm Shift From Industrial Agriculture to Diversified Agroecological Systems*. International Panel of Experts on Sustainable Food Systems.
- Jones, A.D., Shrinivas, A., Bezner-Kerr, R., 2014. Farm production diversity is associated with greater household dietary diversity in Malawi: findings from nationally representative data. *Food Policy* 46, 1–12. <https://doi.org/10.1016/j.foodpol.2014.02.001>.
- Kangmennaang, J., Bezner Kerr, R., Lupafya, E., Dakishoni, L., Katundu, M., Luginaah, I., 2017. Impact of a participatory agroecological development project on household wealth and food security in Malawi. *Food Secur.* 9, 561–576. <https://doi.org/10.1007/s12571-017-0669-z>.
- Kremen, C., Miles, A., 2012. Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities, and trade-offs. *Ecol. Soc.* 17. <https://doi.org/10.5751/ES-05035-170440>.
- Kremen, C., Iles, A., Bacon, C., 2012. Diversified Farming Systems: An Agroecological, Systems-based Alternative to Modern Industrial Agriculture. *Ecol. Soc.* 17. <https://doi.org/10.5751/ES-05103-170444>.
- Kristjansson, P., Neufeldt, H., Gassner, A., Mango, J., Kyazze, F.B., Desta, S., Sayula, G., Thiede, B., Förch, W., Thornton, P.K., Coe, R., 2012. Are food insecure smallholder households making changes in their farming practices? Evidence from East Africa. *Food Secur.* 4, 381–397. <https://doi.org/10.1007/s12571-012-0194-z>.
- Labadarios, D., Steyn, N.P., Nel, J., 2011. How diverse is the diet of adult South Africans? *Nutr. J.* 10, 33. <https://doi.org/10.1186/1475-2891-10-33>.
- Lee, H.G., Erickson Jon, G., Méndez, V. Ernesto, 2014. Supporting rural livelihoods and ecosystem services conservation in the pico Duarte coffee region of the Dominican Republic. *Agroecol. Sustain. Food Syst.* 38 (9), 1078–1107. <https://doi.org/10.1080/21683565.2014.932883>.
- Liang, K.-Y., Zeger, S.L., 1986. Longitudinal data analysis using generalized linear models. *Biometrika* 73, 13–22.
- Lin, B.B., 2011. Resilience in agriculture through crop diversification: adaptive management for environmental change. *BioScience* 61, 183–193. <https://doi.org/10.1525/bio.2011.61.3.4>.
- Loos, Jacqueline, Abson, David J., Chappell, M.J., Hanspach, Jan, Mikulcak, Friederike, Tichit, Muriel, Fischer, Joern, 2014. Putting meaning back into “sustainable intensification”. *Front. Ecol. Environ.* 12, 356–361. <https://doi.org/10.1890/1523-1739.2014.12.356>.
- Lunduka, R., Ricker-Gilbert, J., Fisher, M., 2013. What are the farm-level impacts of Malawi’s farm input subsidy program? A critical review. *Agric. Econ.* 44, 563–579. <https://doi.org/10.1111/agec.12074>.
- M’Kaibi, F.K., Steyn, N.P., Ochola, S., Du Plessis, L., 2015. Effects of agricultural biodiversity and seasonal rain on dietary adequacy and household food security in rural areas of Kenya. *BMC Public Health* 15 (1), 422–432. <https://doi.org/10.1186/s12889-015-1755-9>.
- Masset, E., Haddad, L., Cornelius, A., Isaza-Castro, J., 2012. Effectiveness of agricultural interventions that aim to improve nutritional status of children: systematic review. *BMJ Br. Med. J.* 344 (7843), 16.
- Maxwell, D., Vaitla, B., Coates, J., 2014. How do indicators of household food insecurity measure up? An empirical comparison from Ethiopia. *Food Policy* 47, 107–116.

- <https://doi.org/10.1016/j.foodpol.2014.04.003>.
- Méndez, V. Ernesto, Bacon, C.M., Olson, M., Morris, K.S., Shattuck, A.K., 2010. Agrobiodiversity and shade coffee smallholder livelihoods: a review and synthesis of ten years of research in Central America. *Prof. Geogr.* 62, 357–376.
- Méndez, V. Ernesto, Bacon, Christopher M., Cohen, Roseann, 2013. Agroecology as a transdisciplinary, participatory, and action-oriented approach. *Agroecol. Sustain. Food Syst.* 37 (1), 3–18.
- Messina, J.P., Peter, B.G., Snapp, S.S., 2017. Re-evaluating the Malawian Farm Input Subsidy Programme. *Nat. Plants* 3, 17013. <https://doi.org/10.1038/nplants.2017.13>.
- Miles, M., Huberman, A., Saldana, J., 2014. *Qualitative Data Analysis: a Method Sourcebook*. Sage Publications.
- Morris, S.S., Carletto, C., Hoddinott, J.M., Christiaensen, L.J., 2000. Validity of rapid estimates of household wealth and income for health surveys in rural Africa. *J. Epidemiol. Community Health* 54, 381–387.
- Nangombe, S., Zhou, T., Zhang, W., Wu, B., Hu, S., Zou, L., Li, D., 2018. Record-breaking climate extremes in Africa under stabilized 1.5°C and 2°C global warming scenarios. *Nat. Clim. Chang.* 8 (5), 375.
- National Statistical Office (NSO), 2014. *Malawi Integrated Household Panel Survey, 2010–2013*. Zomba, Malawi.
- National Statistical Office (NSO), ICF, 2017. *2015–16 Malawi Demographic and Health Survey Key Findings*. ICF International, Zomba, Malawi, and Maryland, USA.
- Noiret, B., 2016. Food security in a changing climate: a plea for ambitious action and inclusive development. *Development* 59, 237–242. <https://doi.org/10.1057/s41301-017-0092-y>.
- Nyantakyi-Frimpong, H., Mambulu, F.N., Bezner Kerr, R., Luginaah, I., Lupafya, E., 2016. Agroecology and sustainable food systems: participatory research to improve food security among HIV-affected households in northern Malawi. *Soc. Sci. Med.* 164, 89–99. <https://doi.org/10.1016/j.socscimed.2016.07.020>.
- Nyantakyi-Frimpong, H., Kangmennaang, J., Bezner Kerr, R., Luginaah, I., Dakishoni, L., Lupafya, E., Shumba, L., Katundu, M., 2017. Agroecology and healthy food systems in semi-humid tropical Africa: participatory research with vulnerable farming households in Malawi. *Acta Trop.* 175, 42–49.
- Oliver, B., 2016. “The Earth Gives us so Much”: Agroecology and Rural Women’s Leadership in Uruguay. *Culture, Agriculture, Food and Environment* 38 (1), 38–47. <https://doi.org/10.1111/cuag.12064>.
- Philpott, S.M., Lin, B.B., Jha, S., Brines, S.J., 2008. A multi-scale assessment of hurricane impacts on agricultural landscapes based on land use and topographic features. *Agric. Ecosyst. Environ.* 128, 12–20.
- Ponisio, L.C., M’Gonigle, L.K., Mace, K.C., Palomino, J., Valpine, P., Kremen, C., 2015. Diversification practices reduce organic to conventional yield gap. *Proc R Soc B* 282, 20141396. <https://doi.org/10.1098/rspb.2014.1396>.
- Powell, B., Thilsted, S.H., Ickowitz, A., Termote, C., Sunderland, T., Herforth, A., 2015. Improving diets with wild and cultivated biodiversity from across the landscape. *Food Secur.* 7 (3), 535–554.
- Rabe-Hesketh, S., Skrondal, A., 2005. *Multilevel and Longitudinal Modeling Using Stata*. STATA press, College station, Texas.
- Ribot, J., 2014. Cause and response: vulnerability and climate in the Anthropocene. *J. Peasant Stud.* 41, 667–705. <https://doi.org/10.1080/03066150.2014.894911>.
- Rogé, P., Friedman, A.R., Astier, M., Altieri, M.A., 2014. Farmer Strategies for Dealing with Climatic Variability: A Case Study from the Mixteca Alta Region of Oaxaca, Mexico. *Agroecol. Sustain. Food Syst.* 38 (7), 786–811. <https://doi.org/10.1080/21683565.2014.900842>.
- Ruel, M.T., 2003. Operationalizing dietary diversity: a review of measurement issues and research priorities. *J. Nutr.* 133, 3911S–3926S. <https://doi.org/10.1093/jn/133.11.3911S>.
- Rusinamhodzi, L., Corbeels, M., Nyamangara, J., Giller, K.E., 2012. Maize–grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers in central Mozambique. *Field Crops Res.* 136, 12–22. <https://doi.org/10.1016/j.fcr.2012.07.014>.
- Rutstein, S.O., Johnston, K., 2004. *The DHS Wealth Index*. DHS Comparative Report 6. ORC Macro, Calverton, Maryland.
- Sanderson Bellamy, A., Ioris, A.A.R., 2017. Addressing the Knowledge Gaps in Agroecology and Identifying Guiding Principles for Transforming Conventional Agri-Food Systems. *Sustainability* 9, 330. <https://doi.org/10.3390/su9030330>.
- Schipanski, M.E., MacDonald, G.K., Rosenzweig, S., Chappell, J., Bennett, E.M., Bezner Kerr, R., Blesh, J., Crews, T., Drinkwater, L., Lundgren, J.G., Schnarr, C., 2016. Realizing resilient food systems. *Bioscience* 66 (7), 600–610. <https://doi.org/10.1093/biosci/biw052>.
- Seufert, V., Ramankutty, N., Foley, J.A., 2012. Comparing the yields of organic and conventional agriculture. *Nature* 485, 229–232. <https://doi.org/10.1038/nature11069>.
- Singer, J., Willet, J., 2003. *Applied Longitudinal Data Analysis*. Oxford University Press, Oxford.
- Smith, L., Haddad, L., 2015. Reducing child undernutrition: past drivers and priorities for the Post-MDG era. *World Dev.* 68, 180–204. <https://doi.org/10.1016/j.worlddev.2014.11.014>.
- Snapp, S.S., Blackie, M.J., Gilbert, R.A., Bezner Kerr, R., Kanyama-Phiri, G.Y., 2010. Biodiversity can support a greener revolution in Africa. *Proc. Natl. Acad. Sci.* 107, 20840–20845. <https://doi.org/10.1073/pnas.1007199107>.
- Snapp, S.S., Rohrbach, D.D., Simtowe, F., Freeman, H.A., 2002. Sustainable soil management options for malawi: Can smallholder farmers grow more legumes? *Agriculture, Ecosystems and Environment* 91 (1), 159–174. [https://doi.org/10.1016/S0167-8809\(01\)00238](https://doi.org/10.1016/S0167-8809(01)00238).
- Souza, K.D., Kituyi, E., Harvey, B., Leone, M., Murali, K.S., Ford, J.D., 2015. Vulnerability to climate change in three hot spots in Africa and Asia: key issues for policy-relevant adaptation and resilience-building research. *Reg. Environ. Change* 15, 747–753. <https://doi.org/10.1007/s10113-015-0755-8>.
- Swindale, A., Bilinsky, P., 2006. Development of a universally applicable household food insecurity measurement tool: process, current status, and outstanding issues. *J. Nutr.* 136, 1449S–1452S. <https://doi.org/10.1093/jn/136.5.1449S>.
- Tabachnick, B.G., Fidell, L., 2007. *Using Multivariate Statistics*. Allyn & Bacon/Pearson Education, Boston.
- Verger, E.O., Ballard, T.J., Dop, M.C., Martin-Prevel, Y., 2019. Systematic review of use and interpretation of dietary diversity indicators in nutrition-sensitive agriculture literature. *Glob. Food Sec.* 20, 156–169.
- Waldman, K.B., Ortega, D.L., Richardson, R.B., Clay, D.C., Snapp, S., 2016. Preferences for legume attributes in maize-legume cropping systems in Malawi. *Food Secur.* 8 (6), 1087–1099. <https://doi.org/10.1007/s12571-016-0616-4>.
- Webb, P., Coates, J., Frongillo, E.A., Rogers, B.L., Swindale, A., Bilinsky, P., 2006. Measuring household food insecurity: why it’s so important and yet so difficult to do. *J. Nutr.* 136 (5), 1404S–1408S.
- World Bank, 2017. *Poverty and Equity Databank*. <http://databank.worldbank.org/data/home.aspx>.